GAME REPORT

Survival, Reproduction, Home Ranges, and Resource Selection of Prairie Grouse in Hyde and Hand Counties, South Dakota

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ABSTRACT

Prairie grouse were once found statewide in South Dakota, but conversion of grassland to cropland has reduced the current distribution to areas where suitable landscape-level grasslands occur, mostly in central and western portions of the state. Much of the remaining prairie grouse distribution occurs in areas with good to superb wind power classification. Wind energy development has increased during the last decade with little known about the potential impact on prairie grouse populations. We collected prairie grouse survival, reproduction, resource selection and home range data from 2010 to 2013 on a planned wind energy site during the pre-construction phase. A similar, nearby site with no wind energy development planned was used as a control site.

Nests from 195 individual prairie grouse female were used for nest survival (251 nests) and site selection (257 nests) analysis. Daily nest survival did not vary substantially by site, year, or species. We pooled all nests, and then modeled nest survival as a function of landscape level habitat attributes. Nest survival declined with increased developed habitat patch density within 800 m of the nest. We used logistic regression to model nest site selection as a function of landscape attributes. Prairie grouse selected grassland dominated landscapes and avoided trees for nest site selection.

A total of 223 adult female prairie grouse, 115 located in the control study site and 108 located in the impact study site, were used for survival analysis. We found minimal support for a year, species or site affect. Annual survival was 44.0 ± 0.04%.

The average prairie grouse home range was 1,619.72 ± 336.46 ha and 1,192.47 ± 207.45 ha for the impact and control site, respectively. Home range sizes of prairie grouse did not differ between sites or among years. Resource selection analysis indicated prairie grouse selected for areas with proportionally more grass on the landscape and less trees during the lekking, nesting, and brood rearing season. Our research gives baseline results prior to wind energy development and demonstrates prairie grouse would benefit from management on a landscape scale that protects or enhances large continuous blocks of grassland.

PREFACE

This report summarizes results of research conducted by South Dakota Department of Game, Fish and Parks personnel from February 2010 through April 2013 on the survival, reproduction, and home ranges of greater prairie-chickens and sharp-tailed grouse in a pre-construction wind energy site and in a control site in South Dakota (Study No. 7541 under Pittman-Robertson project W-75-R-56). Funding for this study was furnished by South Dakota Department of Game, Fish and Parks and by the Pittman-Robertson cost sharing. Permission to quote may be obtained from the Wildlife Division Director, South Dakota Department of Game, Fish and Parks, 523 E. Capitol, Pierre, South Dakota, 57501.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

List of Tables (cont.)

Table **Page**

List of Tables (cont.)

Table **Page**

List of Figures

Figure **Page**

List of Figures (cont.)

Figure **Page**

List of Appendices

INTRODUCTION

Greater prairie-chickens (PC, *Tympanuchus cupido*) and sharp-tailed grouse (ST, *Tympanuchus phasianellus*), hereafter prairie grouse, are grassland obligate birds dependent upon large tracts of grassland habitat for much of their life cycle needs (reviewed in Flake et al. 2010). South Dakota is one of only a few landscapes in North America where both of these species exist in stable populations (Svedarsky et al. 2000).

Prairie grouse require large, contiguous grassland landscapes to persist. This specialized requirement makes them ideal candidates to serve as flagship species for conservation planning (Vodehnal and Haufler 2008). Grassland conversion and alteration has ultimately reduced the amount of functional habitat for prairie grouse and other native grassland species. Grassland conversion is identified as the number one threat to these species (Braun et al. 1994, Knopf and Samson 1997, Flake et al. 2010). Grassland loss continues as Reitsma et al. 2014 estimated 1.84 million acres of grassland were lost, mostly to cropland conversion, between 2006 and 2012 in South Dakota.

During the last 5 years, wind energy development companies have identified South Dakota as one of the top geographic locations within the United States (National Wind Energy Association 2012). According to the U.S. Department of Energy, South Dakota's resource potential for wind energy includes vast areas with good to superb wind power classifications. Wind energy development has been recognized as an economic boom to South Dakota and a way to produce alternative energy sources.

Many of the same locations being sought for wind development contain critical habitat for prairie grouse. For example, the Missouri Coteau in central South Dakota still contains large tracts of grassland, is occupied by prairie grouse, and has already experienced some wind energy development. Although the development of wind energy technology is relatively new, the construction of wind towers and their associated infrastructure is occurring at a rapid pace throughout the Great Plains (Pruett et al. 2009 a). Along with the rapid pace of construction, the concern for needed research has been growing (Kuvlesky et al. 2007). Conservation Reserve Program grasslands in southwestern Minnesota without turbines and areas located 180 m from turbines supported mean densities of passerine birds that were four times higher than those in grasslands nearer to turbines (Leddy et al. 1999). Behavioral changes, such as avoidance of infrastructure used to support wind energy development locations have been associated with PC in Kansas (Pruett et al. 2009a, Pruett et al. 2009b). As a result, this avoidance may greatly decrease the amount of usable habitat for prairie grouse (Robel et al. 2004). Reduced lekking attendance and reduced demographic rates of prairie grouse have also been associated with energy development (Hagen 2010).

Maintaining and enhancing prairie grouse habitat will also provide benefits to many other prairie dependent species. Information on potential impacts on prairie grouse by wind development would help South Dakota Game, Fish, and

Parks more efficiently manage prairie grouse populations throughout South Dakota and provide siting recommendations to wind developers that lessen negative impacts on these populations. The following report summarizes the findings of a 3 year, intensive research project looking at the reproductive and biological characteristics of female prairie grouse in Hyde and Hand counties, South Dakota.

Objectives:

1. To annually locate and monitor prairie grouse leks and document their distribution and abundance within a control and impact study area.
2. To determine survival of female prairie grouse within a control and impact study area.
3. To estimate fecundity, including nest success, nesting rates, and nest dispersal of prairie grouse within a control and impact study area.
4. To determine breeding season home ranges of prairie grouse within a control and impact study area.
5. To estimate land-use composition and seasonal habitat use of prairie grouse within a control and impact study area.

STUDY AREA

The study area consisted of a 9,324 ha impact and control site (Figure 1). The study sites reflect the area where most birds were captured and where lek surveys occurred. The analysis areas (Figure 2 and Figure 3) represent a minimum convex polygon of all bird locations buffered by 1.6 km. Both sites were within the northern mixed grass prairie with native vegetation consisting of forbs and medium-tall to tall grasses such as western wheatgrass (*Triticum smithii*), big bluestem (*Andropogon gerardii*), porcupine grass (*Hesperostipa spartea*), and little bluestem (*Schizachyrium scoparium*) (Johnson and Larson 1999). Much of the native uplands were highly encroached by introduced grasses such as smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*). Trees were primarily associated with natural drainages, and in planted stands around dwellings or for protection for livestock and/or wildlife. Both study sites were in close proximity to one another, and climate did not differ between sites. The average annual temperature for these sites is 7.3 degrees C (South Dakota Climate and Weather 2013a). The average annual cumulative precipitation for these study sites is 43.18 cm to 60.96 cm (South Dakota Climate and Weather 2013b).

The control site was within the James River Lowlands level IV Ecoregion of eastern Hyde County South Dakota (Bryce et al. 1998). This glaciated flat to gently rolling landscape of highly productive soils contains high concentrations of temporary and seasonal wetlands. Much of the landscape has been converted to cropland; mostly corn (*Zea maize*), soybeans (*Glycine max*), sunflowers

(*Helianthus* spp.), and wheat (*Triticum* spp.). Dominant landuses within the 66,000 ha analysis area were grassland (52%) and cropland (39%) with the remaining area comprised of hayland, developed land, right of ways, trees, and open water. Land ownership was 98% privately owned with all public lands owned by the South Dakota Department of School and Public Lands (SPL). During the duration of the study, the control site contained no areas leased for wind energy development.

The impact site was within the Southern Missouri Coteau Ecoregion (Bryce et al. 1998). This glaciated area exhibits gentle undulations with well-developed drainages, although scattered areas contain high wetland density. Less tillage occurs here than the James River Lowlands Ecoregion. Dominant landuses within the 45,000 ha site were grassland (66%) and cropland (17%) with the remaining area comprised of hayland, developed land, right of ways, trees, and open water. Most (97%) of the land was privately owned with some land owned by SPL and the United States Fish and Wildlife Service. At the onset of this study in March 2010, 90% of the site was leased for wind energy development.

METHODS

Data Collection

Lek Searches and Counts

We searched both study sites for prairie grouse leks by looking and listening for lek activity during mid-March through April 2010–2012. Searches were conducted ½ hour before sunrise to 2 hours after sunrise, and 1 hour before sunset to ½ hour after sunset. We searched for leks most days regardless of weather conditions; however, all areas were searched at least once under ideal conditions (i.e. calm and sunny morning). We counted the number of male prairie grouse on leks 1–3 times using a spotting scope or binoculars from an ideal vantage point. Male prairie grouse were identified to species or as a hybrid. All leks were marked with a Global Positioning System (GPS). Leks that were inadvertently located outside the study site boundaries were also marked and counted if time allowed.

Female Capture and Monitoring

We captured female PC and ST using walk-in traps on leks during March through April of 2009–2011 (Figure 4) (Schroeder and Braun 1991). Captured birds were sexed by plumage characteristics (Henderson et al. 1967). We fitted females with 10.7 g necklace-style VHF radio transmitters with an expected battery life of 500 days and 6-hour mortality switches (Model #A3950, Advanced Telemetry Systems, Inc., Isanti, MN).

We attempted to locate radio-marked females ≥ 3 times per week from March to August by triangulation using Locate III with a Windows Mobile® capable GPS unit (Nams 2006) or by homing in on birds with a portable radio receiver and hand-held yagi antenna and marking a location with a GPS. Locations using a GPS were completed when the observer estimated they were within 50 m of the marked bird. If the bird flushed at a distance, the observer would mark the point at the best approximated location. From September through February, females were tracked once weekly from public right-of-ways to determine survival. No locations were recorded during this survey period. We periodically used a fixed-wing aircraft equipped with telemetry equipment to search for prairie grouse when they could not be located from roadways.

We flushed females when several locations were localized indicating potential for a nesting bird. We marked nests with a GPS and recorded clutch size. We revisited active nests one time to determine final clutch size. If the clutch size increased between visits, the date of clutch initiation was determined by backdating by the number of eggs from the first visit, assuming one egg was laid per day (Svedarsky 1988). If clutch size did not change between visits, the date of nest initiation was determined by backdating from the hatch date, assuming an incubation period of 24 days (Schroeder and Rob 1993). We monitored nest status either by triangulating the female, or by determining female presence using a portable radio receiver and hand-held yagi antenna. We assumed a nest was active if the female was present. Once the female was located away from the nest location, we determined nest fate. We classified nest fate as successful if ≥ 1 egg hatched, or as unsuccessful if the nest was depredated, abandoned, or otherwise destroyed. A nest was also considered unsuccessful on the day a female died while away from the nest.

Landuse Mapping

We created landuse layers for all 3 years within each analysis region by digitizing in ArcGIS 10.1 (ESRI 2012) and labeling aerial imagery in the field (Figure 5 and Figure 6). We classified the landscape into 6 categories; grassland, tree, developed, alfalfa hay, right-of-way, and cropland with a 0.1 ha minimum mapping unit. Developed areas included farmsteads, buildings, towns, and trees directly surrounding building sites. Right-of-way included hard surface and gravel roads, but not unimproved grass trails. The grassland landuse category included grass and non-alfalfa hayland. We completed ground truthing yearly to find landuse changes that we may not have detected by viewing aerial imagery or landuse raster data. The digitized landscape was converted to GRID raster format with 5 x 5 m cell size and each year was converted to its own raster file using ArcGIS 10.1.

Data Analysis

Nest Survival and Site Selection

We created 400 m, 800 m and 1,600 m shapefile buffers around each nest. We used the buffered shapefiles to clip the landuse GRID layer and landuse attributes were developed for each nest at the 3 spatial scales. We used FRAGSTATS to calculate standard habitat metrics at the patch, class, and landscape level describing the composition and configuration of the landscape at the 400 m, 800 m, and 1,600 m scales (McCarigal et al. 2012) (Appendix A). We repeated this process for an equal number of random points. Because 90% of nests were within 4 km of a trapped lek, we generated equal number of random points as nest locations within this buffer distance for each year. The remaining nests were within 4 km to 8 km of a trapped lek. We generated an equal number of random points as nest locations within this 4 km to 8 km buffer ring for each year.

We screened potential variables using a Multiple Response Permutation Procedure (MRPP) function to determine which variables were different between nest and random sites and successful and unsuccessful nests at the $P < 0.25$ level. A generous significance level was used because very few variables were different at lower levels (e.g. $P < 0.15$). The screening process limited the number of variables to a manageable level prior to nest survival and site selection model development.

We modeled nest site selection as a function of landscape-level variables using logistic regression for each nest at a 400 m, 800 m, and 1,600 m scale. We developed a list of biologically supported a priori models for each scale. Informative variables from each scale were used to build a suite of multi-scale models. We used an information theoretic approach to estimate support for models evaluating nest site selection (Burnham and Anderson 2002). We evaluated the predictive strength of our models using a receiver operation curve (ROC); values between 0.7 and 0.8 were considered acceptable predictive discrimination and values greater than 0.8 were considered excellent predictive discrimination.

We used the nest survival procedure in Program MARK to model daily survival rate (DSR) of nests as a function of covariates that may influence nest survival (White and Burnham 1999). We modeled DSR as a function of study site, year, species, and time trend, and then pooled all data to develop landscape level habitat models. We used an information theoretic approach to evaluate support for candidate models (Burnham and Anderson 2002).

Adult Survival

We used the nest survival procedure in Program MARK to model weekly survival rate (WSR) of prairie grouse because we had ragged telemetry data. We considered site, year, species, season (breeding vs. non-breeding), and time trend as model covariates. We used an information theoretic approach to evaluate support for candidate models (Burnham and Anderson 2002).

Home Range

We calculated prairie grouse breeding season home ranges using locations taken from 1 April to 1 September of 2010–2012. We calculated and established home ranges using the fixed kernel density estimator method (Beyer 2004) to calculate 95% minimum convex polygons (Dunn and Gipson 1977). To ensure accuracy in calculating home ranges, only females with a minimum of roughly 25 locations were used to estimate home range (Seaman et al. 1999, Springer 2003).

We used a Shapiro-Wilk test for normality (Shapiro and Wilk 1965) to determine the distribution of prairie grouse home range size. Data was not normally distributed, so we used a Kruskal-Wallis ranked sum test (Kruskal and Wallis 1952) to test for differences in home range size among years and between sites.

Home Range Resource Selection

We used logistic regression to model resource selection of breeding season (1 April–31 August) prairie grouse home ranges. We generated an equal number of random home ranges as actual home ranges for each year. We calculated the mean and standard error of the estimated prairie grouse home ranges and randomly generated points within each analysis region for both the impact and control sites which were buffered by random distances using above mentioned mean and standard error (Katnik and Wielgus 2005). We used FRAGSTATS to calculate standard habitat metrics (McCarigal et al. 2012) at the patch, class, and landscape level describing the composition and configuration of the landscape for home ranges and randomly generated home ranges. We screened potential variables using an MRPP function to determine which variables were different between home ranges and random home ranges at the $P < 0.25$ level. A generous significance level was used because very few variables were different at lower levels (e.g. $P < 0.15$). The screening process limited the number of variables to a manageable level prior to model development.

We used an information theoretic approach to evaluate support for candidate models (Burnham and Anderson 2002). We evaluated the predictive strength of our models using receiver operating characteristics (ROC); values between 0.7 and 0.8 were considered acceptable predictive discrimination and values greater than 0.8 were considered excellent predictive discrimination.

All statistical analyses were performed in R (version 2.15.2) (R Core Team 2012), packages adehabitatHR (Calenge 2006), aod (Lesnoff and Lancelot 2012), ggplot2 (Wickham 2009), maptools (Bivand and Lewin-Koh 2013), MASS (Venables and Ripley 2002), MuMIn (Barton 2013), pastecs (Ibanez et al. 2013), ResourceSelection (Lele et al. 2013), ROCR (Sing et al. 2005), shapefiles (Stabler 2013), sp (Pebesma et al. 2005), and vegan (Oksanen et al. 2013).

RESULTS

Lek Inventory and Counts

We found a total of 49 leks during the 3 year study. We completed lek counts on 34, 46, and 16 leks in 2010, 2011, and 2012. During 2012, not all leks were counted due to logistical challenges. Mean lek counts for ST, PC, and mixed leks for each year are included in Appendix B.

Female Capture

We captured a total of 195 prairie grouse during this study. In 2010, we captured a total of 18 ST and 18 PC in the control site, and a total of 29 ST and 5 PC in the impact site. Of the birds captured in 2010, 31 were adults, 37 were juveniles, and 2 were of unknown ages. In 2011, we captured a total of 16 ST and 13 PC in the control site, and a total of 24 ST, 3 PC and 1 hybrid in the impact site. Of the birds captured in 2011, 18 were adults, 24 were juveniles, and 14 were of unknown ages. In 2012, we captured a total of 33 ST and 2 PC in the control site, and a total of 33 ST and 1 hybrid in the impact site. Of the birds captured in 2012, 28 were adults, 15 were juveniles, and 25 were of unknown ages.

Nest Phenology and Distribution

Mean hatch date pooled over all 3 years was 19 June for first attempts, 2 July for the second attempt, and 16 July for the third nesting attempt. Average clutch size was 13.5 ± 0.25 for first attempts and 10.4 ± 0.26 for second attempts and 9.4 ± 1.04 for third attempts. Prairie grouse nested a mean 2,496 m (range 66–13,417 m) (Figure 7) and 3,171 m (range 231–18,351 m) (Figure 8) from their lek of capture in the control and impact study areas, respectively. PC nested a mean 2,495 m (range 189–5,080 m) and ST nested a mean 2,916 m (range 280–18,353 m) from their lek of capture.

Nest Site Selection

We analyzed a total of 257 nests for nest site selection. In 2010, we found a total of 21 ST and 22 PC nests in the control site, and a total of 37 ST and 6 PC nests in the impact site. In 2011, we found a total of 26 ST and 23 PC nests in the control site, and a total of 28 ST nests and 4 PC nests in the impact site. In 2012, we found a total of 37 ST nests and 7 PC nests in the control site, and a total of 45 ST nests, and 1 hybrid nests in the impact site.

Of 268 nests found, 255 were in grassland and 13 were in alfalfa hay fields. No nests were found in row crop or small grain fields. The MRPP variable screening process of FRAGSTATS habitat metrics yielded variables at all landscape scales with $P < 0.25$ (i.e. 400 m, 800 m, and 1,600 m) (Appendix C). At the 400 m scale (Table 1), the most parsimonious model indicated nest site selection increased with the amount of grassland on the landscape ($\beta = 0.03$; 95% CI, 0.03–0.04) and was reduced by the amount of trees on the landscape ($\beta = -0.54$; 95% CI, -1.01 to -0.22) (*AUC* = 0.743) (Table 2).

At the 800 m scale (Table 3), the most parsimonious model was similar and indicated a positive association with the amount of grassland on the landscape ($\beta = 0.03$; 95% CI, 0.02–0.04), and negative associations with the amount trees on the landscape ($\beta = -0.50$; 95% CI, -0.77 to -0.26) (*AUC* = 0.733) (Table 2). Grass LSI was included in the top model, but the 90% CI for the β estimate overlapped zero so it was not considered an informative variable. Grass mean patch area was also in the top model, but its β estimate was essentially zero, indicating minimal importance.

At the 1,600 m scale (Table 4), a positive association was found in relation to the amount of grassland found on the landscape (β = 0.03; 95% CI, 0.01–0.04), grassland patch density (β = 1.58; 95% CI, 1.04–2.20), and a negative association with the amount of trees on the landscape (β = -0.57; 95% CI, -0.92 to -0.24) (*AUC* = 0.737) (Table 2). Grass mean patch area was not considered an informative variable because its β estimate was essentially zero.

The most parsimonious post-hoc multi-scale model included one landscape variable from each scale (Table 5). Positive associations were found between percent of grassland on the landscape at the 400 m scale (β = 0.03; 95% CI, 0.022–0.04) and grassland patch density at the 1,600 m scale (β = 0.93; 95% CI, 0.53–1.39) while the amount of trees on the landscape at the 800 m scale had a negative association with nest site selection (β = -0.67; 95% CI, -0.99 to -0.39) (AUC = 0.783) (Table 6).

Nest Survival

A total of 251 nests were used for nest survival analyses. In 2010, we found 21 ST and 22 PC nests in the control site, and 37 ST and 6 PC nests in the impact site. In 2011, we found a total of 26 ST and 19 PC nests in the control site, and a total of 28 ST and 4 PC nests in the impact site. In 2012, we found a total of 35 ST and 7 PC nests in the control site and 46 ST nests in the impact site.

The constant nest survival model was the highest AICc ranked non-habitat model (Table 7). Overall DSR (constant model) was 0.967 (SE = 0.002) (Figure 9). This equates to a nest survival of 31.0 ± 3.6% (36 exposure days). The model containing the variable site was also competitive. Daily survival rate for nests in the control study area was 0.965 (SE = 0.004) while the DSR in the impact study area was 0.971 (SE = 0.004) (Figure 9). The DSR was considered similar between species and among years.

We pooled all nest survival data before considering landscape-level covariates. The MRPP variable screening of FRAGSTATS habitat metrics yielded variables at the 400 m and 800 m scales with $P < 0.25$, but no significant variables at the 1,600 m scale with $P < 0.25$) (Appendix D).

There were 4 competing models at the 400 m scale. The top two AICc ranked models were related and showed a negative association with % developed land and developed patch density. A time trend model and intercept only model (DSR = 0.968; SE = 0.003) (Table 8) were also within 2 AICc units of the top model. The time trend model was not considered competitive because the parameter estimate 95% confidence interval overlapped zero.

At the 800 m scale, two models were competitive (Table 8). The top-ranked model showed developed patch density had a negative influence on nest success ($\beta = -0.62$; 95% CI, -1.09 to -0.15) (Table 9, Figure 10). The second-ranked 800 m scale model showed a negative impact from the percent of developed land ($\beta = -0.26$; 95% CI, -0.46 to -0.06) (Table 9, Figure 11).

Adult Female Survival

We used a total of 223 adult female for analysis. Of the 223 adult female, 115 were from the control study site and 108 were from the impact study site. The highest AICc ranked model included the single variable, season (Figure 12, Table 10). Weekly survival was higher during the breeding season (0.988; 95% 95% CI, 0.983 to 0.991) than the non-breeding season (0.982; 95% CI, 0.977 to 0.986). Overall combined annual survival was 44.0% (95% CI, 36.8 to 50.9) and was a competing model**.**

Home Range

We used locations from 66 and 61 prairie grouse for home range analysis for the control and impact study areas, respectively. We used locations from 98 ST, 27 PC and 2 hybrids. We collected 4,722 locations over 3 field seasons. In 2010, we collected 677 locations from the control site and 696 locations from the impact site. In 2011, we collected 531 locations from the control site and 521 locations from the impact site. In 2012, we collected 1,180 locations from the control site and 1,117 locations from the impact site. We found no significant difference in home range size between site (X^2 = 0.48, P = 0.49), among year year (X^2 = 0.39, P = 0.15), or between species (hybrids excluded, X^2 = 2.68, P = 0.26). The average home range size was 1,397.69 ha ± 194.41.

Resource Selection

We used 66 and 61 prairie grouse breeding season home ranges calculated for the control and impact study area for analysis, respectively. An equal number of random home ranges for both the impact and control study areas were generated. The MRPP variable screening process of FRAGSTATS habitat metrics resulted in 6 variables with $P < 0.25$ (Appendix E). Prairie grouse selected home ranges with higher amounts of grassland ($\beta = 0.05$; 95% CI, 0.04–0.07) and lesser amounts of trees ($\beta = -1.09$; 95% CI, -1.64 to -0.60) (Table 11 and Table 12).

DISCUSSION

Nests

Nest Site Selection

Our results suggest prairie grouse selected nest sites within grassland-dominated landscapes and avoided trees when considering only macro-scale habitat variables. Nearly all prairie grouse nests were in grassland with mean grassland cover ranging from 74% at the 1,600 m scale to 88% at the 400 m scale. Odds of nest site selection increased with total grass cover (odds ratio = 1.03 at all three scales), but was most strongly explained by avoidance of trees. The avoidance of trees was similar at all three spatial scales as odds of site selection decreased by 0.57–0.61 for every 1% increase in trees. Avoidance of trees for nest site selection has been found for greater prairie-chickens in Kansas (McNew et al. 2014) and Nebraska (Matthews et al. 2013). Prairie grouse may have selected grassland dominated areas with minimal amounts of trees to minimize negative impacts from nest predators associated with trees (Kuehl and Clark 2002, Svedarsky et al. 2003, Manzer and Hannon 2005). It was surprising that grass patch density was positively correlated with nest site selection considering the concurrent selection of landscapes with a higher proportion of grass. This suggests a landscape in which the grassland was more fragmented into multiple patches was more likely to be selected for a nest site. It is possible that landscapes with more grassland patches were more likely to contain specific patches with desirable micro-habitat conditions. We did not collect vegetative habitat variables at the nest site, but these characteristics have been found to influence nest site selection in prairie grouse (Buhnerkempe et al. 1984, Prose et al. 2002, McNew et al. 2013, Matthews 2013). Our most parsimonious post-hoc multi-scale model did not substantially improve model fit over the individual scale models, but did have the highest AUC value. The multi-scale model reiterated that prairie grouse preferred grassland dominated landscapes and avoided trees when selecting nest sites.

Nest Success

Success was higher in the impact study site where 66% of the landscape was grassland versus only 52% for the control site. Overall nest success for this study (31.0 ± 3.6%; 36 exposure days) was substantially lower than the most recent prairie grouse study in South Dakota located on the Fort Pierre National Grasslands (FPNG) in South Dakota (Norton 2005). Norton (2005) found nest success to be 80.2% for PC's and 71.6% for ST within this block of primarily publicly-owned grassland with intensively managed grazing regimes. Norton (2005) hypothesized that nest survival was enhanced on the FPNG which has regulated rotational grazing and also requires the rest of grasslands for increased residual cover which has been linked to increase nest survival. The FPNG is also a highly contiguous block of grass which may reduce the impacts from nest predators which target edge habitat for foraging (Phillips et al. 2003). Norton (2005) documented the highest nest survival rates of prairie grouse in the published literature. Our nest survival rate was similar to McNew et al. 2014 (30% apparent) and slightly lower than Matthew et al. 2013 (40% apparent), but well below 50%, a level suggested for stable populations (Westemeier 1979). Estimates of nest survival for 22 studies of PCs average 49% (Bergerud and Gratson 1988).

Developed patch density and percent developed were both predicted to reduce nest survival at the 400m and 800m scales. Nest survival was predicted to decline from 33.6% (95% CI: 27.2–40.1%) to 14.2% (95% CI: 5.6–26.8%) when developed patch density increases from 0.0 to 1.0 at the 800m scale. Nest survival was predicted to decline from 31.4% (95% CI: 25.5–37.4%) to 18.8% (95% CI: 9.4–31.5%) when developed patch density increases from 0.0 to 1.0 at the 400m scale. Reduced nest survival in close proximity to farmsteads, abandoned buildings, and associated trees were likely in response to increased mammalian and avian predators (Lariviere et al 1999, Svedarsky et al. 2003, Manzer and Hannon 2005,).

Adult Female Survival

We found little evidence of a site, year, or species effect on female survival. To our knowledge, this was the first year-round prairie grouse survival study in South Dakota. Annual survival was similar to PC in heavily and moderately fragmented landscapes of Kansas, but lower than in highly contiguous grasslands (McNew 2012). Our estimates were on the lower end of other published annual survival rates for PC (41–56%, Hamerstrom and Hamerstrom 1973, Wisdom and Mills 1997, Augustine and Sandercock 2010). Our breeding season survival rate (76%) was similar to PC (84%) and ST (80%) on the Fort Pierre National Grassland Norton (2005) and much higher than reported for PC in North Dakota (52%, Newell 1987), PC in Minnesota (58%, Svedarsky 1979), and ST in Alberta, Canada (53%, Manzer 2003). Similar to Norton (2005), we found little difference between the survival rates of PC and ST indicating similar reproductive ecology. We found survival was higher during the breeding season versus the non-breeding season which is opposite of that found by Winder et al. (2013) and Augustine and Sandercock (2011) in Kansas. We hypothesize that prairie grouse have a higher predation risk in South Dakota where snow typically covers the ground during much of the non-breeding season. Additionally, winter snowfall was well above average during this study (average snowfall = 87 cm, average during study = 144 cm) (South Dakota Climate and Weather 2015a and 2015b). Reduced survival has been documented in sympatric populations of ring-necked pheasants during severe winters (reviewed in Flake et al. 2012).

Home Range

Little is known about prairie grouse home range size in South Dakota. Fredrickson (1995) found an average annual home range size of 418 ha for 7 transplanted female PCs, but home range size was based on as few as 5 locations. Fredrickson (1995) found an average annual home range size of

120 ha for 5 resident female PCs based on at least 12 locations each. Our breeding season home range size (1,398 ha) was smaller than annual home ranges calculated for greater prairie-chickens in Oklahoma (2,593 ha) (Patten et al. 2011), but larger than for sharp-tailed grouse in Colorado (205 ha, male and female combined) (Giesen 1987) or Idaho (190 ha) (Marks and Marks 1987).

Resource Selection

Similar to nest site selection, prairie grouse in our study selected grassland dominated landscapes and avoided trees during the entire breeding season. Home ranges were comprised of 76% grassland versus only 59% for randomly generated home ranges. Trees comprised nearly twice as much of the area within randomly generated home ranges (0.96%) as home ranges (0.52%). The selection for grassland dominated landscapes with fewer trees may increase survival due to fewer predators. McNew et al (2012) found higher survival in intact grasslands versus fragmented grasslands where predator densities were thought to be higher.

MANAGEMENT IMPLICATIONS

This study provides baseline prairie grouse ecology data for a control and impact site in central South Dakota. We found very little evidence that ecology of prairie grouse varied by study site which is ideal for a before after control impact study design. This information will be very valuable for evaluating the potential impacts of wind energy development if development occurs in the impact site and a post-construction study is completed. Our results are consistent with past research in that prairie grouse select for and are most successful in tracts of un-fragmented grasslands for reproduction. Management efforts to encourage the retention of these important habitats will benefit prairie grouse populations.

ACKNOWLEDGEMENTS

We would like to thank our field technicians who helped collect the field data. We would also like to thank the land owners on which this study was completed. Without their cooperation, this study would not have taken place. We would also like to thank Dr. Troy Grovenburg for assistance in statistical analyses and SD GFP staff for their help in data collection and reviewing this report.

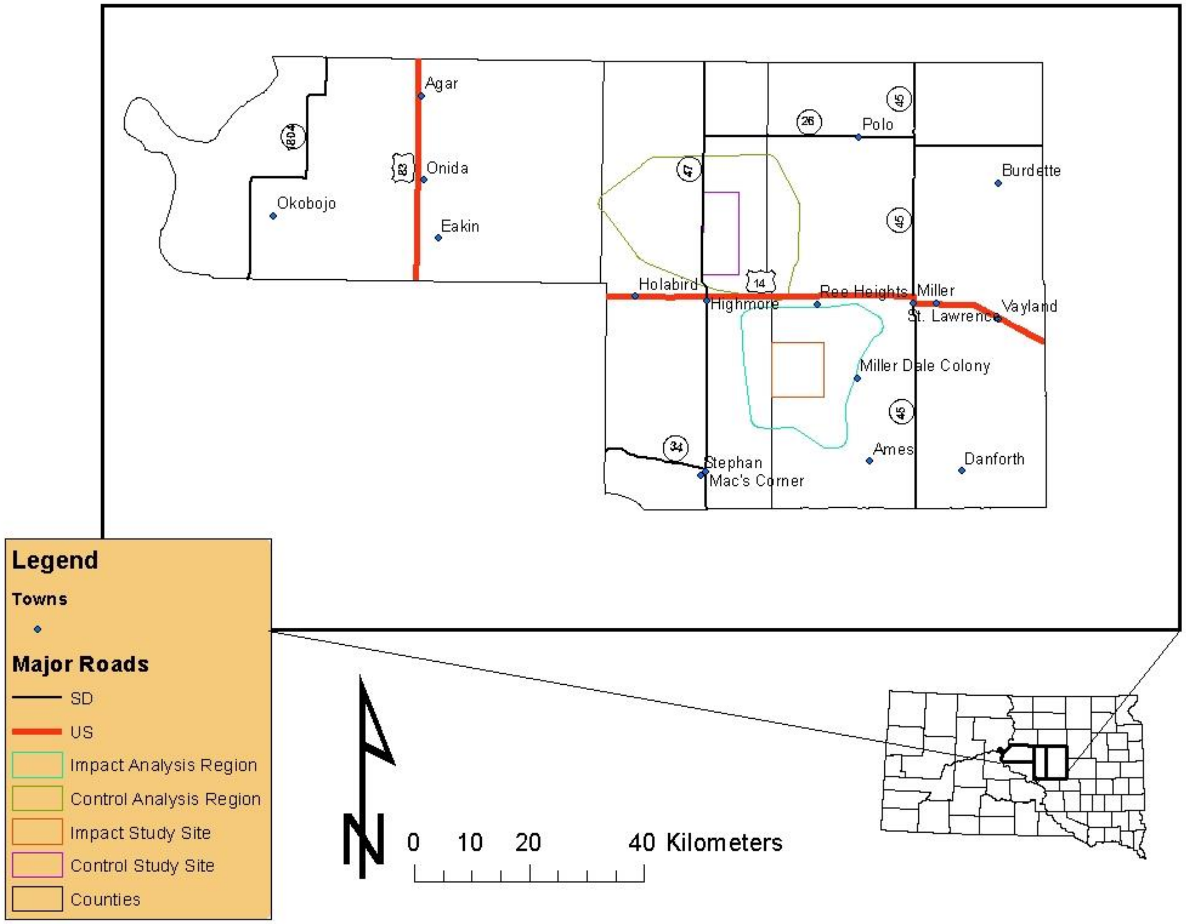

Figure 1. Map of the control and impact study areas and analysis regions in Hyde and Hand counties, South Dakota, 2010–2012.

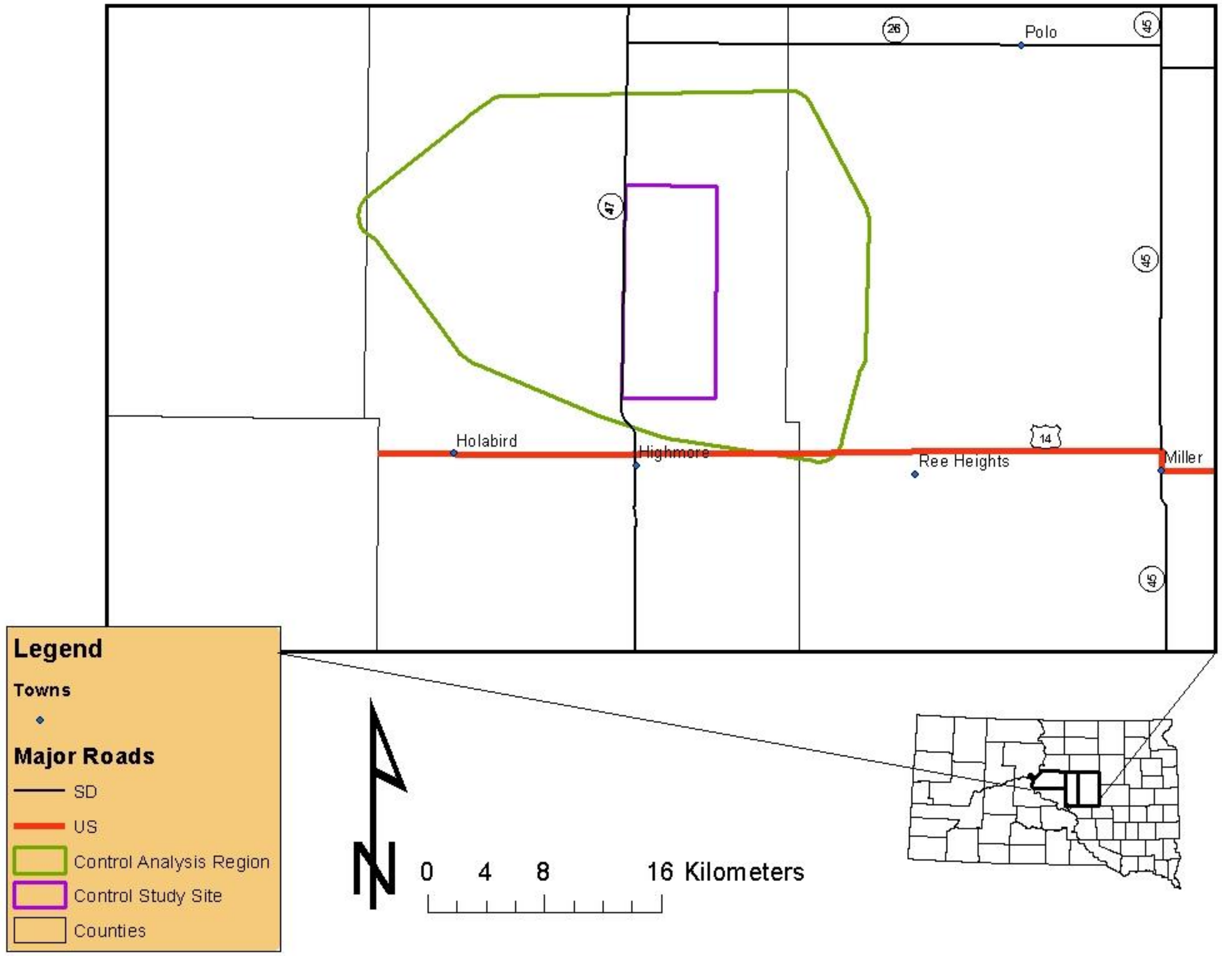

Figure 2. Map of the control study area and analysis region in Hyde and Hand counties, South Dakota, 2010–2012.

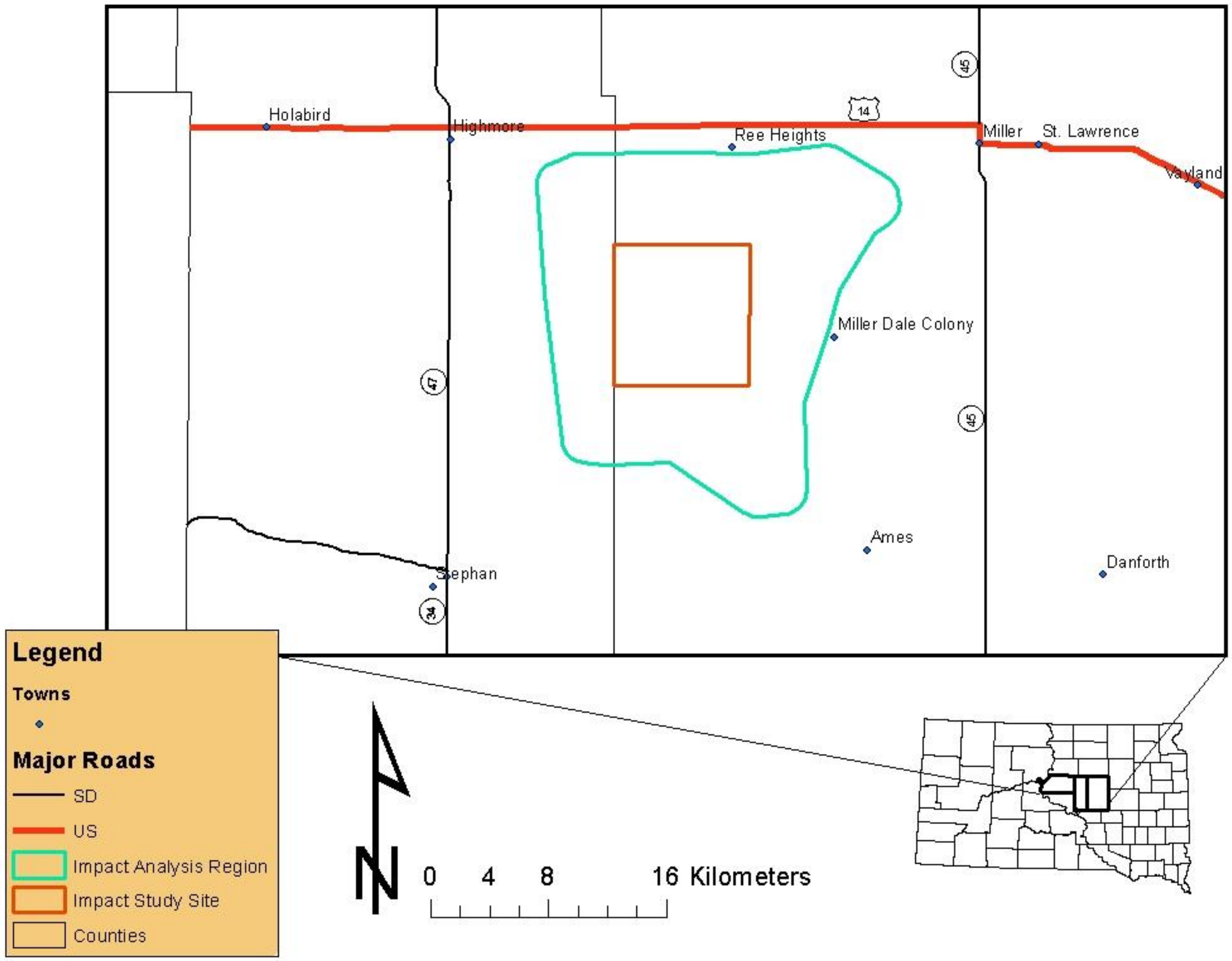

Figure 3. Map of the impact study area and analysis region in Hyde and Hand counties, South Dakota, 2010–2012.

Figure 4. Walk-in trap used to capture prairie grouse in Hyde and Hand counties, South Dakota, April 2010.

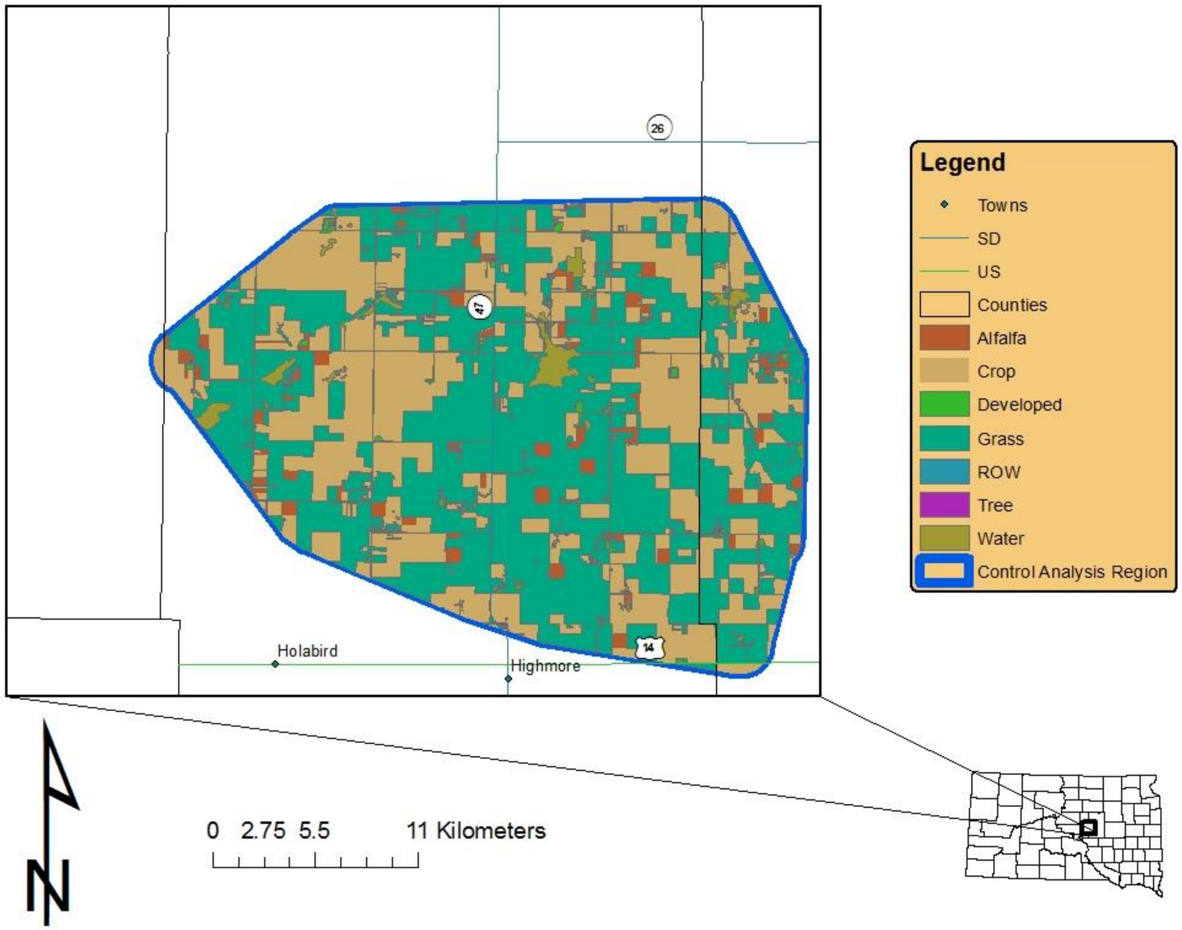

Figure 5. Landuse within control analysis region in 2012.

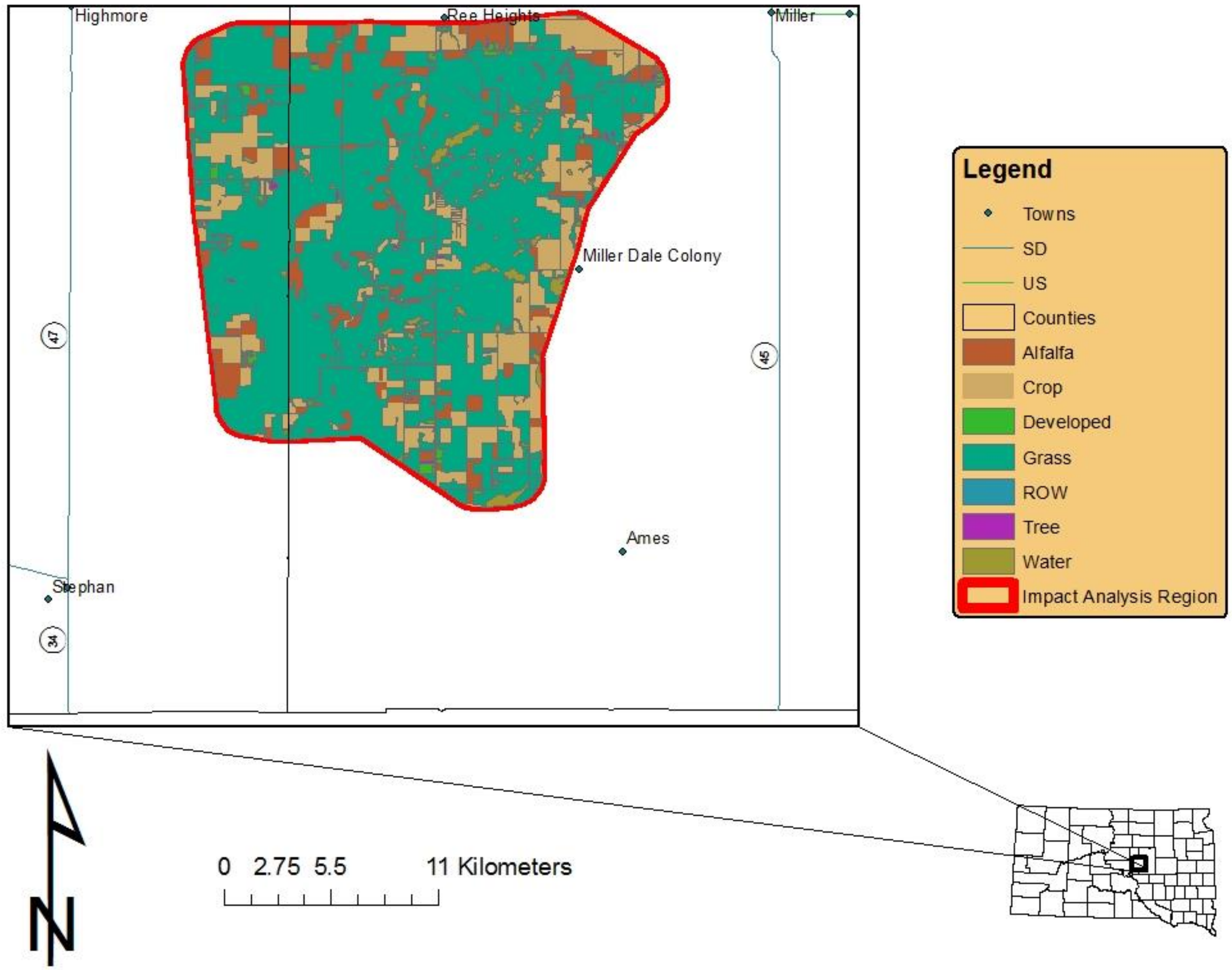

Figure 6. Landuse within impact analysis region in 2012.

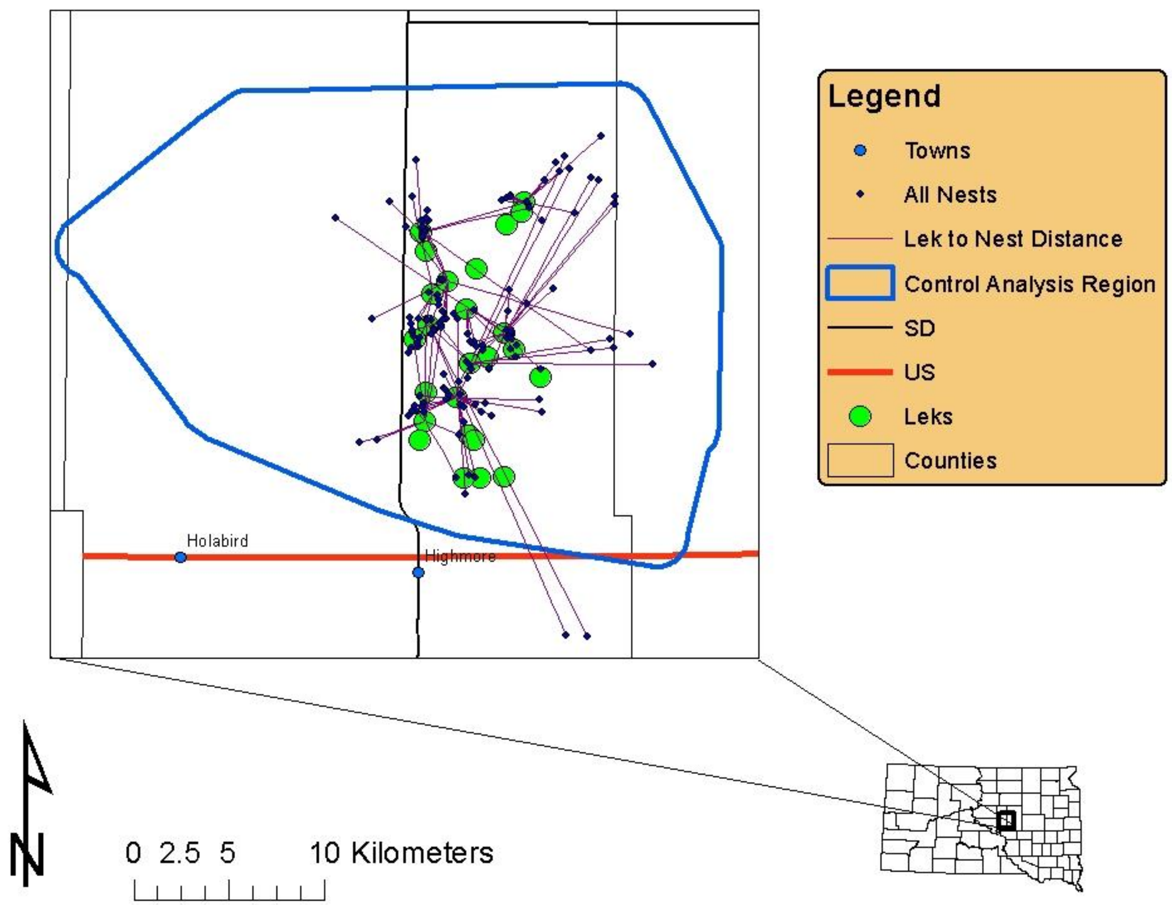

Figure 7. Map of prairie grouse leks found in the control study area in Hyde County, South Dakota, 2010–2012. This map also shows the nest dispersal from lek of capture.

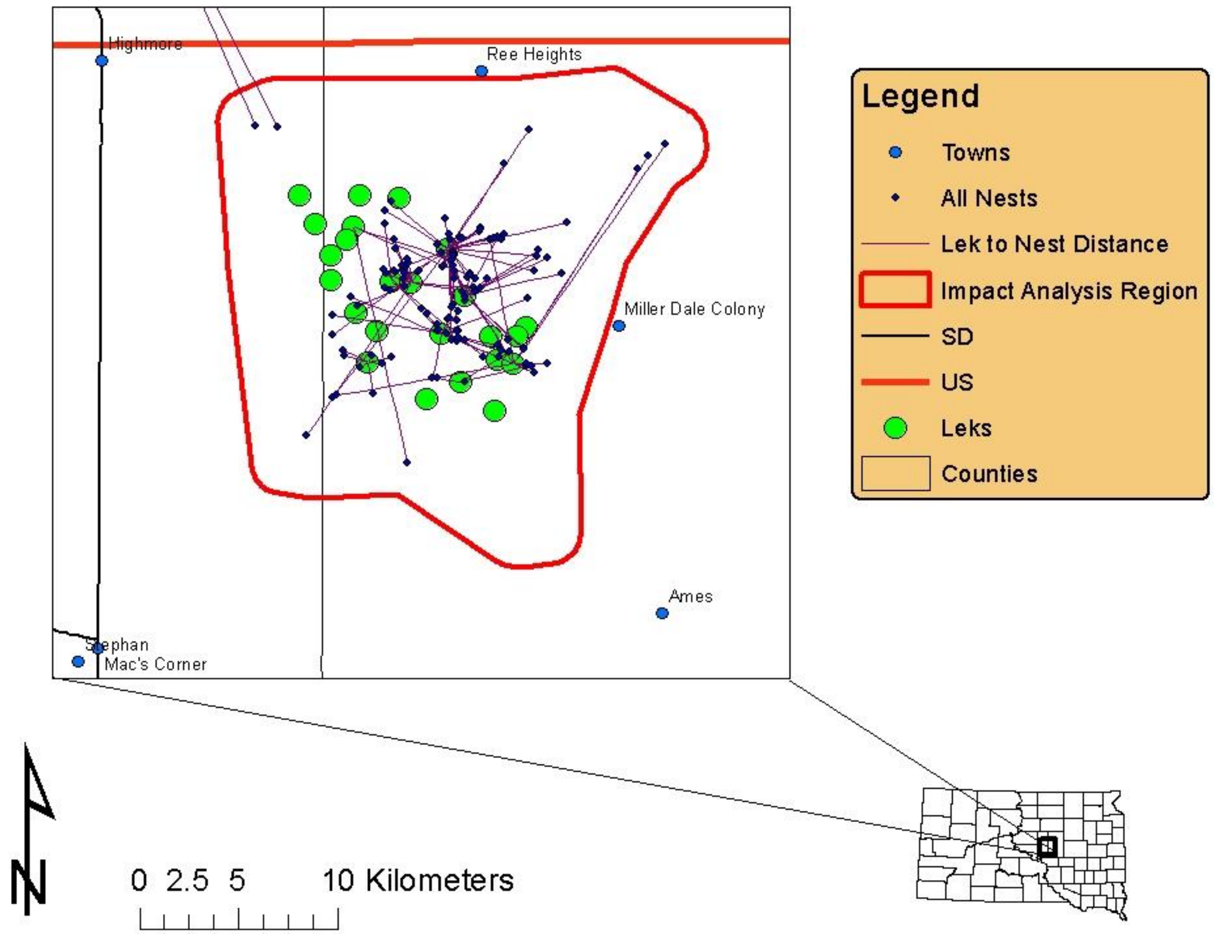

Figure 8. Map of prairie grouse leks found in the impact study area in Hyde and Hand counties, South Dakota, 2010–2012. This map also shows the nest dispersal from lek of capture.

Table 1. Comparison of competing logistic regression models for prairie grouse nest site selection at the 400 m scale in Hyde and Hand counties, South Dakota, 2010–2012. Models are ranked by Akaike's Information Criterion adjusted for small sample size (AICc); K is the number of parameters for each model, ΔAICc is the difference of each model's AICc from the top model, and ω_i is the Akaike weight.

Model	K	AICc	ΔAICc	ωi
%Grass + %tree	2	511.90	0.00	0.58
%Grass + grass ED[a] + %tree	3	513.90	1.96	0.22
%Grass + grass ED + grass mean patch area + %tree	4	515.90	3.92	0.08
%Grass + grass ED + grass mean patch area + %tree + %ROW[b]	5	516.20	4.31	0.07
%Grass + grass ED + grass mean patch area + %tree + %developed	5	517.80	5.81	0.03
%Grass + grass ED + grass mean patch area + %tree + %developed + %ROW	6	518.10	6.18	0.03
%Grass + %ROW	2	526.10	14.21	0.00
%Grass + grass ED	2	526.60	14.67	0.00
%Grass + grass mean patch area	2	526.90	14.99	0.00
%Grass + grass ED + %developed	3	527.40	15.43	0.00
%Grass + grass ED + %ROW	3	527.40	15.44	0.00
%Grass	1	527.50	15.60	0.00
%Grass + %developed	2	527.70	15.80	0.00
%Grass + grass ED + grass mean patch area	3	528.30	16.36	0.00
%Grass + grass ED + grass mean patch area + %developed	4	529.20	17.22	0.00
%Grass + grass ED + grass mean patch area + %ROW	4	529.30	17.33	0.00
Constant (null model)	0	613.30	101.37	0.00

[a] ED = edge density.
[b] ROW = right of way.

Table 2. Coefficient (β) estimates, conditional odds ratios, and 95% confidence intervals in the most parsimonious logistic regression model for each scale predicting nest site selection of prairie grouse in Hyde and Hand counties, South Dakota, 2010–2012.

				95% Profile Likelihood CI	
Scale	**Variable**	**β estimate**	**Conditional Odds Ratio**	**Lower**	**Upper**
1600m					
	Intercept	-3.04			
	%Grass	0.03	1.03	1.01	1.04
	Grass patch density	1.58	4.88	2.83	9.04
	Grass mean patch area	0.00[a]	1.00[a]	1.00[a]	1.00[a]
	%Tree	-0.57	0.57	0.40	0.79
800m					
	Intercept	-1.94			
	%Grass	0.04	1.04	1.03	1.06
	Grass LSI	-0.28	0.75	0.47	1.21
	Grass mean patch area	-0.01	0.99	0.98	0.99
	%Tree	-0.56	0.57	0.42	0.75
400m					
	Intercept	-2.30			
	%Grass	0.03	1.03	1.02	1.04
	%Tree	-0.54	0.58	0.37	0.80

[a] Rounded

Table 3. Comparison of competing logistic regression models for prairie grouse nest site selection at the 800 m scale in Hyde and Hand counties, South Dakota, 2010–2012. Models are ranked by Akaike's Information Criterion adjusted for small sample size (AICc); K is the number of parameters for each model, ΔAICc is the difference of each model's AICc from the top model, and ω_i is the Akaike weight.

Model	**K**	**AICc**	**ΔAICc**	**ωi**
%Grass + grass LSI[a] + grass mean patch area + %tree	4	520.20	0.00	0.41
%Grass + grass LSI + grass mean patch area + %tree + %ROW[b]	5	521.80	1.53	0.19
%Grass + grass LSI + grass mean patch area + %tree + %developed	5	521.90	1.66	0.18
%Grass + %tree	2	523.00	2.75	0.01
%Grass + grass LSI + grass mean patch area + %tree + %developed + %ROW	6	523.40	3.13	0.01
%Grass + grass LSI + %tree	3	524.90	4.69	0.04
%Grass + grass LSI + grass mean patch area + %developed	4	535.90	15.65	0.00
%Grass + grass LSI + grass mean patch area	3	537.00	16.75	0.00
%Grass + %developed	2	537.90	17.70	0.00
%Grass + grass LSI + grass mean patch area + %ROW	4	538.60	18.39	0.00
%Grass + grass LSI + %developed	3	539.10	18.86	0.00
%Grass + grass LSI	2	539.70	19.50	0.00
%Grass	1	540.50	20.23	0.00
%Grass + grass LSI + %ROW	3	541.10	20.89	0.00
%Grass + grass mean patch area	2	542.00	21.72	0.00
%Grass + %ROW	2	542.50	22.22	0.00
Constant (null model)	0	613.30	93.07	0.00

[a] LSI = grass landscape shape index
[b] ROW = right-of-way

Table 4. Comparison of competing logistic regression models for prairie grouse nest site selection at the 1600 m scale in Hyde and Hand counties, South Dakota, 2010–2012. Models are ranked by Akaike's Information Criterion adjusted for small sample size (AICc); K is the number of parameters for each model, ΔAICc is the difference of each model's AICc from the top model, and ω_i is the Akaike weight.

Model	**K**	**AICc**	**ΔAICc**	**ωi**
%Grass + grass patch density + grass patch area mean + %tree	4	530.00	0.00	0.67
%Grass + grass patch density + grass patch area mean + %tree + %developed	5	532.05	2.05	0.24
%Grass + grass patch density + %tree	3	534.50	4.54	0.07
%Grass + grass patch density + grass patch area mean + %developed	4	538.10	8.09	0.01
%Grass + grass patch density + grass patch area mean	3	539.90	9.91	0.01
%Grass + grass patch density + %developed	3	543.30	13.34	0.00
%Grass + grass patch density	2	547.40	17.41	0.00
%Grass + %tree	2	569.40	39.39	0.00
%Grass + %developed	2	569.40	39.44	0.00
%Grass	1	569.90	39.90	0.00
%Grass + grass patch area mean	2	571.80	41.78	0.00
Constant (null model)	0	613.30	83.33	0.00

Table 5. Comparison of competing multi-scale logistic regression models for prairie grouse nest site selection in Hyde and Hand counties, South Dakota, 2010–2012. Models are ranked by Akaike's Information Criterion adjusted for small sample size (AICc); K is the number of parameters for each model, ΔAICc is the difference of each model's AICc from the top model, and ω_i is the Akaike weight. The number behind each variable name indicates the variable scale (m).

Model	**K**	**AICc**	**ΔAICc**	**ωi**
GrassPD1600[a] + %tree800 + %grass400	4	487.40	0.00	1.00
GrassPD1600 + %grass800 + %tree400	4	501.60	14.23	0.00
%Tree800 + %grass400	3	508.90	21.57	0.00
GrassPD1600 + grassLSI800[b] + %grass400	4	509.60	22.27	0.00
Grass area mean1600 + %tree800 + %grass400	4	510.40	23.06	0.00
GrassPD1600 + grass area mean800 + %grass400	4	513.00	25.66	0.00
%Grass800 + %tree400	3	522.00	34.61	0.00
Grass area mean1600 + %grass800 + %Tree400	4	523.30	35.93	0.00
%Tree1600 + grassLSI800 + %grass400	4	528.50	41.11	0.00
Grass area mean1600 + grassLSI800 + %grass400	4	531.30	43.88	0.00
%Grass1600 + %tree400	3	543.00	55.68	0.00
%Grass1600 + grassLSI800 + %tree400	4	543.20	55.86	0.00
%Grass1600 + %tree800	3	544.70	57.29	0.00
%Grass1600 + grass area mean800 + %tree400	4	544.80	57.43	0.00
Constant (null model)	1	613.30	125.94	0.00

[a] PD = patch density
[b] LSI = landscape shape index

Table 6. Coefficient (β) estimates, conditional odds ratios, and 95% confidence intervals in the most parsimonious multi-scale logistic regression model for prairie grouse nest site selection in Hyde and Hand counties, South Dakota, 2010–2012.

Variable	**β**	**Conditional Odds Ratio**	**95% Profile Likelihood CI**	
			Lower	**Upper**
Intercept	-2.85			
%Tree800	-0.67	0.51	0.37	0.68
%Grass400	0.03	1.03	1.02	1.04
GrassPD1600	0.93	2.54	1.70	4.02

Table 7. Comparison of non-habitat nest survival models in Hyde and Hand counties, South Dakota, 2010–2012. Models are ranked by Akaike's Information Criterion adjusted for small sample size (AICc); K is the number of parameters for each model, ΔAICc is the difference of each model's AICc from the top model, and ω_i is the Akaike weight. Site is a two-level factor of control and impact. Year is a three-level factor of 2010, 2011, and 2012. Species is a two-level factor of sharp-tailed grouse and prairie-chickens.

Model	**K**	**AICc**	**ΔAICc**	**ωi**
Constant	1	988.96	0.00	0.36
Site	2	989.75	0.78	0.24
Species	2	990.96	1.99	0.13
Year	3	991.24	2.28	0.12
Site + Year	4	991.90	2.94	0.08
Species + Year	4	993.01	4.05	0.05
Site*Year	6	995.56	6.59	0.01
Species*Site*Year[a]	11	1003.32	14.36	0.00

[a] Only sharp-tailed grouse nests were available for analyses within the impact study site in 2012.

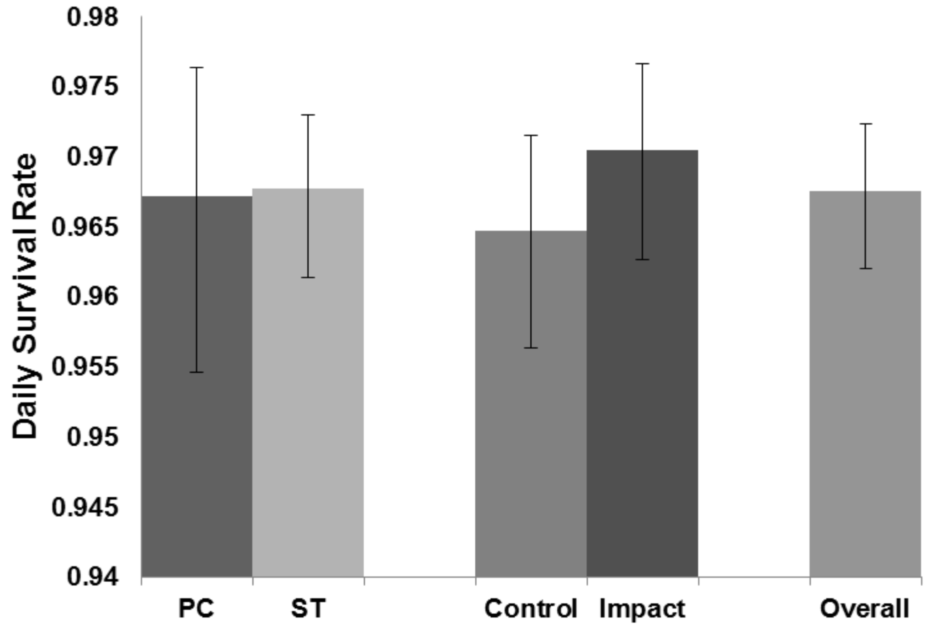

Figure 9. Daily nest survival rate comparisons between greater prairie-chickens and sharp-tailed grouse, the control and impact study site, and overall (most parsimonious model), 2010–2012. Error bars indicate the 95% confidence interval.

Table 8. Comparison of competing nest survival models for prairie grouse in Hyde and Hand counties, South Dakota, 2010–2012. Models are ranked by Akaike's Information Criterion adjusted for small sample size (AICc); K is the number of parameters for each model, ΔAICc is the difference of each model's AICc from the top model, and ω_i is the Akaike weight. A multi-response permutation procedure revealed no significant variables at the 1,600 m scale.

Scale	Model	K	AICc	ΔAICc	ωi
400m	%Developed	2	987.18	0.00	0.24
	Developed patch density	2	987.83	0.65	0.17
	Time trend	2	987.90	0.72	0.16
	Grass patch area mean + %developed	3	988.52	1.34	0.12
	Grass patch area mean + developed patch density	3	988.88	1.70	0.10
	Constant	1	988.96	1.78	0.10
	Grass patch area mean	2	989.71	2.53	0.07
	Weather[a]	2	990.34	3.16	0.05
	Time	121	1145.90	158.72	0.00
	Weather + time	122	1275.98	288.80	0.00
800m					
	Developed patch density	2	985.02	0.00	0.39
	%Developed	2	985.47	0.45	0.31
	Time trend	2	987.90	2.88	0.09
	Tree patch density	2	988.51	3.49	0.07
	%tree	2	988.62	3.60	0.06
	Constant	1	988.96	3.94	0.05
	Weather	2	990.34	5.32	0.03
	Time	121	1145.90	160.88	0.00
	Weather + time	122	1275.98	290.96	0.00

[a] Weather variable indicates effect of ≥ 1.0 cm occurring during a day

Table 9. Coefficient (β) estimates and 95% confidence intervals for habitat-based nest survival models with informative variables in Hyde and Hand counties, South Dakota, 2010–2012.

			95% CI	
Scale	**Variable**	**β**	**Lower**	**Upper**
400m	Intercept	1.21	1.18	1.24
	Intercept	1.71	1.71	1.71
	%Developed	-0.2	-0.36	-0.03
	Intercept	1.71	1.71	1.71
	Developed Patch Density	-0.37	-0.74	-0.002
	Time trend	0.01	-0.00[a]	0.02
800m	Intercept	3.48	3.30	3.66
	Developed Patch Density	-0.62	-1.09	-0.15
	Intercept	3.46	3.29	3.64
	%Developed	-0.26	-0.46	-0.06

[a] Rounded

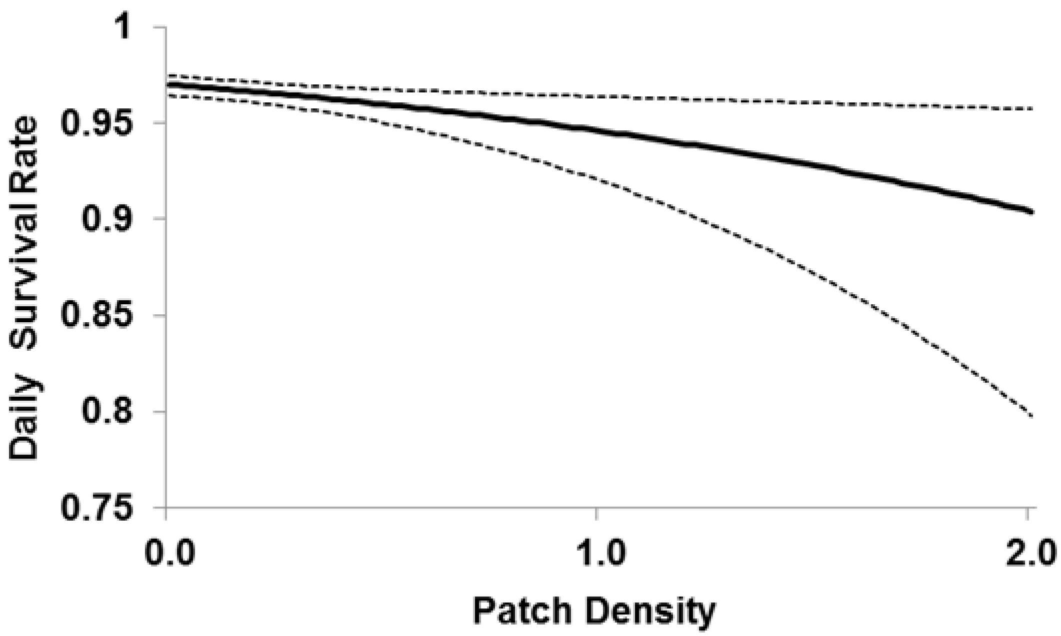

Figure 10. Daily nest survival rate of prairie grouse nests as a function of developed patch density (patches/100 ha) at 800 m scale from the nest location in Hyde and Hand counties, South Dakota, 2010–2012.

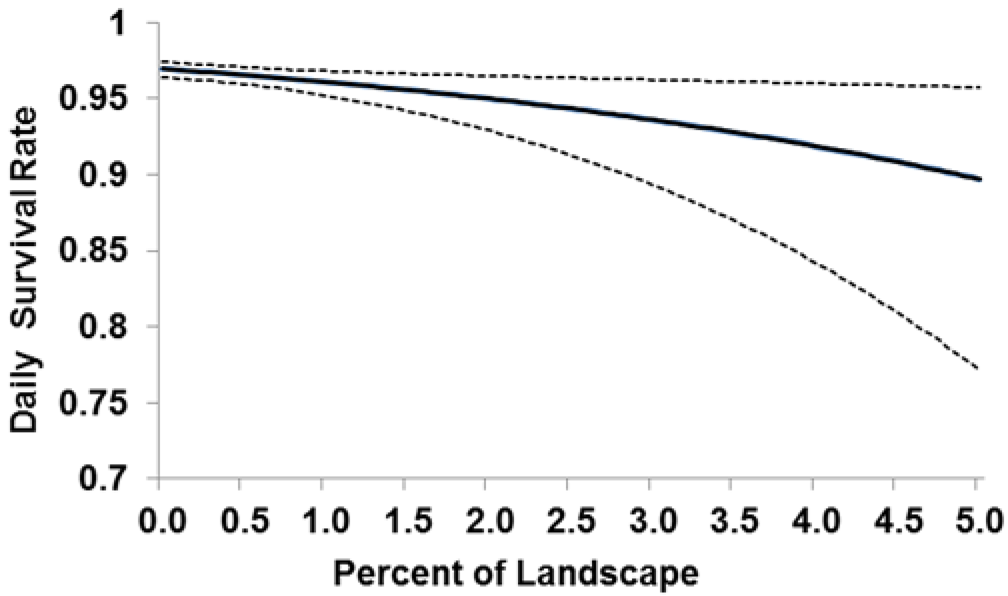

Figure 11. Daily nest survival rate of prairie grouse nests as a function of percent developed habitat at 800 m scale from the nest location in Hyde and Hand counties, South Dakota, 2010–2012.

Figure 12. Annual and seasonal survival rate comparisons between greater prairie-chickens and sharp-tailed grouse, the control and impact study site, overall survival, and seasons, 2010–2013. Error bars indicate the 95% confidence interval.

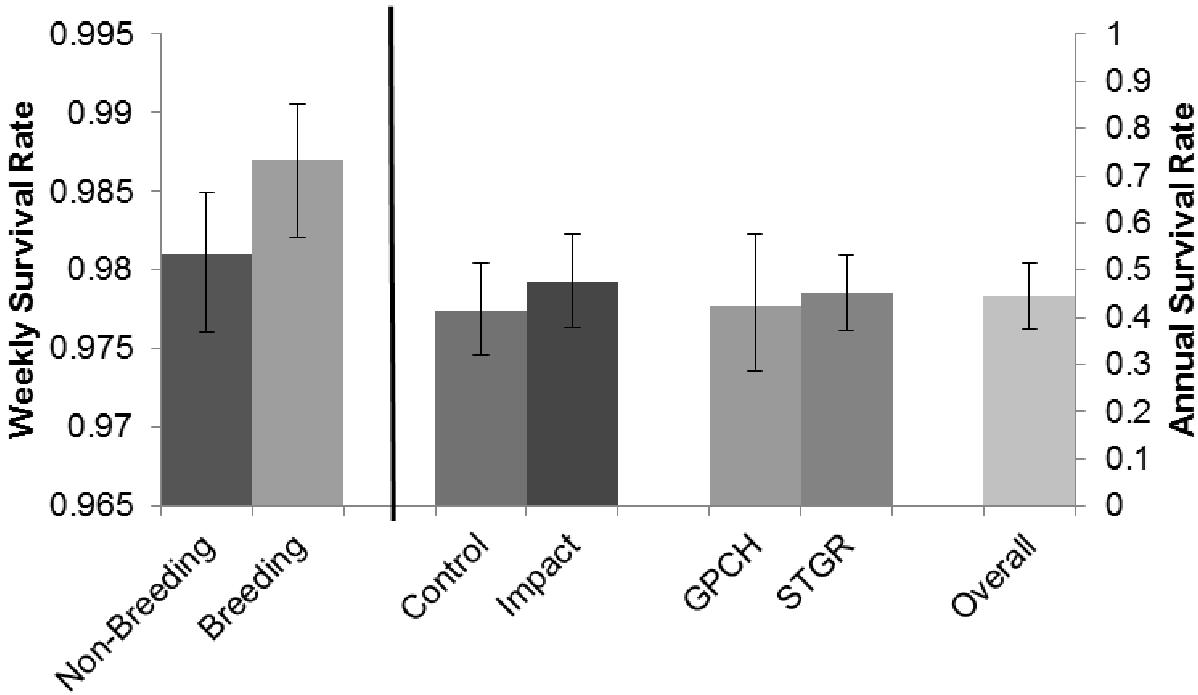

Table 10. Competing models for prairie grouse annual survival in Hyde and Hand counties, South Dakota, 2010–2013; Models are ranked by Akaike's Information Criterion adjusted for small sample size (AICc); K is the number of parameters for each model, ΔAICc is the difference of each model's AICc from the top model, and ω_i is the Akaike weight. Season is a two-level factor of breeding (weeks 14–35) and non-breeding (weeks 1–13 and 36–52). Site is a two-level factor of control and impact. Species is a two-level factor of greater prairie-chicken and sharp-tailed grouse. Year is a three-level factor of 2010, 2011, and 2012.

Model	**K**	**AICc**	**Δ AICc**	**ωi**
Season	2	977.61	0.00	0.47
Constant	1	979.48	1.86	0.18
Season + Site	4	980.69	3.08	0.10
Site	2	980.77	3.16	0.09
Species	2	981.38	3.77	0.07
Year	3	982.58	4.96	0.03
Year + Site	6	983.34	5.72	0.02
Year + Species	6	985.89	8.27	0.01
Year*Species*Site	12	989.94	12.33	0.00

Table 11. Comparison of competing logistic regression models for breeding season home range level habitat selection of prairie grouse in Hyde and Hand counties, South Dakota, 2010–2012. Models are ranked by Akaike's Information Criterion adjusted for small sample size (AICc); K is the number of parameters for each model, ΔAICc is the difference of each model's AICc from the top model, and ω_i is the Akaike weight.

Model	K	AICc	ΔAICc	ωi
%Grass + %tree	2	284.20	0.00	0.41
%Grass + %developed + %tree	3	285.00	0.76	0.28
%Grass + grassLSI[a] + %developed + %tree	4	286.70	2.51	0.12
%Grass + grassLSI + %developed + %tree + %ROW[b]	5	287.40	3.17	0.08
%Grass + %developed	2	289.00	4.84	0.04
%Grass + grassLSI + %developed	3	289.20	5.01	0.03
%Grass + grassLSI	2	298.40	14.15	0.02
%Grass	1	302.80	18.57	0.01
%Grass + grassED[c]	2	303.60	19.40	0.00
%Grass + %ROW	2	304.60	20.41	0.00

[a] LSI = landscape shape index
[b] ROW = right of way
[c] ED = edge density

Table 12. Coefficient (β) estimates, conditional odds ratios, and 95% confidence intervals in the most parsimonious logistic regression model for predicting prairie grouse home range habitat composition vs. random home range habitat composition in Hyde and Hand counties, South Dakota, 2010–2012.

			95% Profile Likelihood CI	
Variable	**β estimate**	**Conditional Odds Ratio**	**Lower**	**Upper**
Intercept	-2.77			
%Grass	0.05	1.05	1.04	1.07
%Tree	-1.09	0.34	0.19	0.55

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APPENDIX

Appendix A. Landscape level variables calculated using FRAGSTATS and their associated definitions for class and patch metrics.

Variable	Name	Definition
PD	Patch Density	The number of patches of the corresponding patch type divided by total landscape area (m^2), multiplied by 10,000 and 100 (to convert to 100 hectares).
ED	Edge Density	The sum of the lengths (m) of all edge segments involving the corresponding patch type, divided by the total landscape area (m^2), multiplied by 10,000 (to convert to hectares).
LSI	Landscape Shape Index	The total length of edge (or perimeter) involving the corresponding class, given in number of cell surfaces, divided by the minimum length of class edge (or perimeter) possible for a maximally aggregated class.
AREA_MN	Area Mean	The sum, across all patches in the landscape, of the corresponding patch metric values, divided by the total number of patches.
NLSI	Normalized Landscape Shape Index	Normalized Landscape shape index is the normalized version of the landscape shape index (LSI) and, as such, provides a simple measure of class aggregation or clumpiness.
PLAND	Percent of Landscape	The percentage the landscape comprised of the corresponding patch type.
TA	Total Area	The total area (m^2) of the landscape, divided by 10,000 (to convert to hectares).
NP	Number of Patches	The number of patches in the landscape.
TE	Total Edge	The sum of lengths (m) of all edge segments in the landscape.
AREA_AM	Area Weighted Mean	The sum, across all patches of the corresponding patch type, of the corresponding patch metric value multiplied by the proportional abundance of the patch.

AREA_MD	Area Median	The value of the corresponding patch metric for the patch representing the midpoint of the rank order distribution of patch metric values for patches of the corresponding patch type.
AREA_SD	Area Standard Deviation	The square root of the sum of the squared deviations of each patch metric value from the mean metric value of the corresponding patch type, divided by the number of patches of the same type; that is, the root mean squared error (deviation from the mean) in the corresponding patch metric.
AREA_CV	Area Coefficient of Variation	The standard deviation divided by the mean, multiplied by 100 to convert to a percentage, for the corresponding patch metric.
PR	Patch Richness	The number of patch types present.
PRD	Patch Richness Density	The standardized patch richness by a per area basis.
SHDI	Shannon's Diversity Index	A specific habitat diversity index
SIDI	Simpson's Diversity Index	A specific habitat diversity index
SHEI	Shannon's Evenness Index	A specific habitat evenness index
SIEI	Simpson's Evenness Index	A specific habitat evenness index
CA	Total Class Area	The sum of the areas (m^2) of all patches of the corresponding patch type, divided by 10,000 (to convert to hectares).

Appendix B. Mean maximum male lek counts by lek type for 2010–2012, control and impact study areas, Hyde and Hand counties South Dakota.

		Leks Counted by Type			Mean Lek Attendance by Type		
	Total Leks	**PC**	**ST**	**Mixed**	**PC**	**ST**	**Mixed**
2010	34	17	14	3	7	11	12
2011	43	18	12	13	8	15	14
2012	16	6	7	3	10	13	25

Appendix C. Landscape level variables, P-values, means, and standard errors for random points and nests for use in nest site selection models.

		Nests		Random	
Variable	***P*-Value**	**Mean**	**SE**	**Mean**	**SE**
PD1600	0.001	3.20	0.18	2.75	0.08
ED1600	0.003	27.88	1.12	27.62	0.73
LSI1600	0.002	3.11	0.08	3.09	0.05
AREA_MN1600	0.031	51.40	2.62	51.07	2.49
PD800	0.001	3.39	0.21	4.16	0.18
ED800	0.001	20.32	1.17	28.77	1.21
LSI800	0.001	1.85	0.04	2.15	0.04
AREA_MN800	0.004	54.67	3.38	45.04	2.84
PD400	0.001	4.91	0.26	7.92	0.40
ED400	0.001	14.31	1.33	29.43	1.80
LSI400	0.001	1.38	0.02	1.65	0.03
AREA_MN400	0.001	30.47	1.19	22.02	0.98
GrassPLAND1600	0.001	74.23	1.13	59.62	1.66
GrassPD1600	0.001	0.82	0.06	0.57	0.02
GrassED1600	0.002	21.22	0.76	18.14	0.55
GrassLSI1600	0.038	2.70	0.06	2.61	0.05
GrassAREA_MN1600	0.003	213.73	15.08	161.21	1.01
GrassNLSI1600	0.004	0.01	0.001	0.01	0.001
TreePLAND1600	0.006	0.70	0.05	0.89	0.05
TreePD1600	0.006	0.74	0.06	0.03	0.03
TreeED1600	0.049	4.78	0.36	5.28	0.30
TreeAREA_MN1600	0.077	1.10	0.07	1.24	0.07
DevPLAND	0.004	0.63	0.06	0.89	0.07
DevPD1600	0.494	0.26	0.01	0.23	0.01
DevED1600	0.051	1.78	0.14	2.15	0.14
DevAREA_MN1600	0.015	2.36	0.23	3.14	0.26
CropPLAND1600	0.001	15.46	1.12	27.58	1.52
CropPD1600	0.705	0.48	0.03	0.46	0.02
CropED1600	0.004	9.22	0.57	11.05	0.47
CropAREA_MN1600	0.001	36.84	3.39	76.13	6.58
ROWPLAND1600	0.125	0.82	0.05	0.83	0.04
ROWPD1600	0.295	0.14	0.01	0.14	0.01
GrassPLAND800	0.001	82.17	1.27	59.48	2.03
GrassPD800	0.226	1.11	0.08	1.12	0.06
GrassED800	0.141	17.18	0.92	18.55	0.85
GrassLSI800	0.001	1.65	0.04	1.79	0.05

Appendix C (cont.)

GrassAREA_MN800	0.001	116.54	4.70	81.01	4.33
GrassNLSI800	0.093	0.10	0.02	0.07	0.01
TreePLAND800	0.001	0.30	0.04	0.92	0.09
TreePD800	0.002	0.46	0.06	0.72	0.06
TreeED800	0.001	2.11	0.29	5.41	0.53
TreeAREA_MN800	0.001	0.27	0.04	0.62	0.06
DevPLAND800	0.001	0.30	0.06	0.89	0.14
DevPD800	0.001	0.14	0.02	0.31	0.03
DevED800	0.001	0.85	0.15	2.19	0.28
DevAREA_MN800	0.002	0.44	0.09	1.03	0.16
CropPLAND800	0.001	9.38	1.04	26.89	1.81
CropPD800	0.004	0.59	0.05	0.78	0.04
CropED800	0.001	5.89	0.5	11.50	0.69
CropAREA_MN800	0.001	11.08	1.55	32.79	2.79
ROWPLAND800	0.033	0.63	0.06	0.79	0.06
ROWPD800	0.154	0.26	0.02	0.28	0.02
ROWED800	0.069	6.56	0.66	8.01	0.58
GrassPLAND400	0.001	88.14	1.51	58.76	2.40
GrassPD400	0.001	2.55	0.10	2.76	0.14
GrassED400	0.001	12.83	1.15	18.97	1.30
GrassLSI400	0.001	1.29	0.02	1.37	0.05
GrassAREA_MN400	0.001	39.79	1.05	24.55	1.21
GrassNLSI400	0.001	0.42	0.03	0.19	0.02
TreePLAND400	0.001	0.08	0.02	1.04	0.17
TreePD400	0.001	0.25	0.06	0.96	0.14
TreeED400	0.001	0.82	0.22	5.75	0.92
TreeAREA_MN400	0.001	0.03	0.01	0.25	0.04
DevPLAND400	0.003	0.11	0.07	0.77	0.22
DevPD400	0.001	0.07	0.03	0.33	0.06
DevED400	0.002	0.24	0.12	1.83	0.45
DevAREA_MN400	0.002	0.05	0.03	0.28	0.08
CropPLAND400	0.001	4.56	0.95	27.21	2.18
CropPD400	0.001	0.70	0.08	1.62	0.11
CropED400	0.001	3.63	0.51	11.66	0.96
CropAREA_MN400	0.001	2.23	0.47	11.04	0.97
ROWPLAND400	0.001	0.43	0.08	0.82	0.09
ROWPD400	0.001	0.36	0.11	0.67	0.07
ROWED400	0.002	4.40	0.82	8.21	0.90

Appendix D. Landscape level variables, P-values, means, and standard errors for successful and unsuccessful nests.

		Successful		Unsuccessful	
Variable	***P*-Value**	**Mean**	**SE**	**Mean**	**SE**
PD1600	0.767	3.35	0.24	3.40	0.21
ED1600	0.972	28.60	1.55	28.80	1.25
LSI1600	0.986	3.16	0.11	3.17	0.09
AREA_MN1600	0.851	47.39	3.26	49.29	2.84
PD800	0.778	3.31	0.25	3.50	0.25
ED800	0.705	19.54	1.60	21.14	1.33
LSI800	0.699	1.82	0.06	1.88	0.05
AREA_MN800	0.967	54.58	4.63	52.95	3.67
PD400	0.685	4.80	0.37	5.10	0.32
ED400	0.87	14.09	1.80	14.81	1.48
LSI400	0.888	1.38	0.03	1.39	0.03
AREA_MN400	0.696	30.93	1.62	30.21	1.35
GrassPLAND1600	0.318	76.72	1.41	74.31	1.18
GrassPD1600	0.711	0.80	0.08	0.83	0.06
GrassED1600	0.809	21.95	1.03	22.13	0.87
GrassLSI1600	0.874	2.77	0.09	2.75	0.07
GrassAREA_MN1600	0.734	215.62	20.52	202.02	15.73
GrassNLSI1600	0.027	0.02	0.00	0.01	0.00
TreePLAND1600	0.645	0.68	0.06	0.75	0.06
TreePD1600	0.974	0.81	0.09	0.83	0.07
TreeED1600	0.74	5.10	0.57	5.26	0.43
TreeAREA_MN1600	0.308	1.01	0.11	1.02	0.06
DevPLAND	0.314	0.52	0.06	0.67	0.07
DevPD1600	0.687	0.23	0.02	0.25	0.02
DevED1600	0.518	1.65	0.17	1.93	0.16
DevAREA_MN1600	0.162	1.90	0.27	2.37	0.23
CropPLAND1600	0.595	13.68	1.38	15.21	1.21
CropPD1600	0.767	0.46	0.04	0.47	0.03
CropED1600	0.704	9.47	0.90	9.13	0.60
CropAREA_MN1600	0.511	31.68	3.35	38.83	4.06
ROWPLAND1600	0.435	0.81	0.06	0.79	0.05
ROWPD1600	0.231	0.15	0.01	0.14	0.01

Appendix D (cont.)

GrassPD800	0.474	1.07	0.08	1.10	0.09
GrassPLAND800	0.499	83.92	1.56	82.31	1.38
GrassLSI800	0.712	1.64	0.05	1.67	0.04
GrassAREA_MN800	0.489	120.91	6.73	117.67	5.07
GrassNLSI800	0.684	0.11	0.03	0.09	0.02
TreePLAND800	0.252	0.25	0.05	0.36	0.05
TreePD800	0.186	0.38	0.08	0.55	0.08
TreeED800	0.23	1.85	0.37	2.74	0.43
TreeAREA_MN800	0.369	0.21	0.04	0.29	0.04
DevPLAND800	0.012	0.13	0.05	0.34	0.07
DevPD800	0.008	0.08	0.03	0.17	0.03
DevED800	0.01	0.45	0.18	0.99	0.17
DevAREA_MN800	0.006	0.15	0.06	0.54	0.10
CropPLAND800	0.478	8.33	1.27	8.68	1.11
CropPD800	0.469	0.53	0.07	0.56	0.05
CropED800	0.327	5.82	0.74	5.57	0.55
CropAREA_MN800	0.717	9.69	2.03	10.82	1.63
ROWPLAND800	0.798	0.54	0.08	0.60	0.07
ROWPD800	0.554	0.23	0.03	0.27	0.03
ROWED800	0.659	5.62	0.82	6.42	0.72
GrassPLAND400	0.451	89.78	1.66	87.74	1.71
GrassPD400	0.5	2.41	0.13	2.59	0.12
GrassED400	0.997	13.09	1.63	13.00	1.27
GrassLSI400	0.909	1.29	0.03	1.30	0.02
GrassAREA_MN400	0.269	41.77	1.28	39.65	1.17
GrassNLSI400	0.918	0.41	0.05	0.42	0.04
TreePLAND400	0.694	0.11	0.04	0.11	0.03
TreePD400	0.447	0.24	0.08	0.37	0.09
TreeED400	0.589	0.99	0.39	1.26	0.37
TreeAREA_MN400	0.424	0.04	0.02	0.04	0.01
DevPLAND400	0.078	0.00	0.00	0.14	0.08
DevPD400	0.181	0.02	0.02	0.09	0.04
DevED400	0.064	0.01	0.01	0.32	0.15
DevAREA_MN400	0.068	0.00	0.00	0.07	0.04
CropPLAND400	0.575	3.66	1.06	4.74	1.05
CropPD400	0.599	0.66	0.10	0.68	0.10
CropED400	0.566	3.35	0.60	4.04	0.69

Appendix D (cont.)

CropAREA_MN400	0.754	1.84	0.53	2.25	0.52
ROWPLAND400	0.473	0.31	0.10	0.42	0.09
ROWPD400	0.38	0.28	0.08	0.40	0.08
ROWED400	0.362	3.06	0.95	4.32	0.90
Distance to Edge	0.635	446.76	363.81	418.63	0.00

Appendix E. Landscape level variables, P-values, means, and standard errors for random and actual home ranges.

Variable	*P*-Value	Home Range Mean	Home Range SE	Random Home Range Mean	Random Home Range SE
Area	0.001	1397.69	194.41	2395.81	152.31
TA	0.001	1397.65	194.40	2396.89	152.38
NP	0.001	40.78	5.46	61.84	5.10
PD	0.001	3.61	0.22	2.51	0.11
TE	0.001	41032.95	6328.35	72837.13	5431.40
ED	0.005	25.85	1.21	28.49	0.89
LSI	0.001	3.56	0.18	4.53	0.17
AREA_MN	0.003	44.05	4.01	50.65	2.55
AREA_AM	0.001	388.07	39.89	664.71	55.38
AREA_MD	0.352	10.54	2.67	7.28	1.18
AREA_RA	0.001	599.42	70.11	1048.42	78.56
AREA_SD	0.001	107.12	7.14	154.69	7475.00
AREA_CV	0.006	276.36	13.01	342.04	16.17
PR	0.001	5.84	0.17	6.95	0.13
PRD	0.001	1.20	0.10	0.49	0.04
SHDI	0.001	0.70	0.03	0.91	0.02
SIDI	0.001	0.36	0.01	0.47	0.01
SHEI	0.001	0.42	0.02	0.48	0.01
SIEI	0.001	0.45	0.02	0.55	0.02
GrassCA	0.001	992.22	139.68	1481.78	114.91
GrassPLAND	0.001	76.08	1.26	58.80	1.90
GrassNP	0.011	9.11	1.00	11.84	1.11
GrassPD	0.001	1.05	0.08	0.52	0.03
GrassTE	0.001	30562.17	4609.03	49692.01	3853.76
GrassED	0.124	20.58	0.88	19.19	0.66
GrassAREA_MN	0.07	139.31	13.30	154.60	9.76
GrassAREA_AM	0.001	476.06	50.83	795.74	74.19
GrassAREA_MD	0.131	72.37	14.12	46.77	7.27
GrassAREA_RA	0.001	551.19	71.29	937.76	82.95
GrassAREA_SD	0.001	166.51	15.32	267.00	20.61
GrassAREA_CV	0.05	149.18	8.38	183.68	11.12
GrassNLSI	0.001	0.03	0.01	0.01	0.00

Appendix E (cont.)

GrassLSI	0.001	3.14	0.15	3.87	0.14
CropCA	0.001	245.76	42.62	600.52	49.60
CropPLAND	0.001	12.51	1.12	29.38	1.99
CropNP	0.001	5.59	0.67	8.30	0.55
CropPD	0.001	0.54	0.05	0.41	0.03
CropTE	0.001	13847.09	2055.09	27092.05	1989.90
CropED	0.001	8.14	0.62	11.85	0.57
CropAREA_MN	0.001	29.98	3.81	91.33	10.81
CropAREA_AM	0.001	71.04	11.47	226.76	23.27
CropAREA_MD	0.001	20.00	2.84	56.63	10.89
CropAREA_RA	0.001	97.05	17.36	287.08	28.54
CropAREA_SD	0.001	29.62	4.82	96.39	9.92
CropAREA_CV	0.001	70.79	5.58	112.20	5.22
CropNLSI	0.001	0.01	0.00	0.01	0.00
CropLSI	0.001	2.42	0.16	3.31	0.13
DevCA	0.001	9.03	1.92	22.36	2.14
DevPLAND	0.001	0.43	0.05	0.84	0.06
DevNP	0.001	3.06	0.54	5.38	0.47
DevPD	0.003	0.18	0.02	0.20	0.01
DevTE	0.001	2550.35	503.74	5348.94	481.86
DevED	0.001	1.25	0.14	1.99	0.14
DevAREA_MN	0.001	1.56	0.20	3.91	0.31
DevAREA_AM	0.001	2.47	0.30	6.70	0.49
DevAREA_MD	0.001	1.34	0.18	3.03	0.30
DevAREA_RA	0.001	2.75	0.44	8.07	0.75
DevAREA_SD	0.001	0.94	0.14	2.79	0.23
DevAREA_CV	0.001	33.71	4.08	66.06	4.27
DevNLSI	0.001	0.01	0.00	0.02	0.00
DevLSI	0.001	1.53	0.16	2.57	0.14
ROWCA	0.001	11.61	2.08	20.71	1.86
ROWPLAND	0.001	0.63	0.05	0.80	0.05
ROWNP	0.027	1.41	0.11	1.56	0.08
ROWPD	0.001	0.20	0.02	0.09	0.01
ROWTE	0.001	11192.99	2076.44	20743.39	1741.72
ROWED	0.003	6.62	0.54	8.09	0.43
ROWAREA_MN	0.001	5.66	0.88	14.64	1.59
ROWAREA_AM	0.001	7.88	1.38	17.62	1.71

Appendix E (cont.)

ROWAREA_MD	0.001	5.05	0.80	14.06	1.60
ROWAREA_RA	0.061	5.36	1.44	6.99	1.15
ROWAREA_SD	0.061	2.35	0.60	3.33	0.55
ROWAREA_CV	0.263	25.21	3.53	30.76	3.71
ROWNLSI	0.001	0.09	0.01	0.11	0.00
ROWLSI	0.001	6.30	0.56	10.13	0.49
TreeCA	0.001	10.38	1.83	25.08	2.28
TreePLAND	0.001	0.52	0.05	0.96	0.06
TreeNP	0.001	9.79	1.64	16.81	1.59
TreePD	0.015	0.63	0.06	0.63	0.04
TreeTE	0.001	7044.21	1212.95	15024.45	1372.40
TreeED	0.001	3.81	0.36	5.58	0.36
TreeAREA_MN	0.001	0.81	0.07	1.66	0.11
TreeAREA_AM	0.001	1.44	0.14	3.11	0.20
TreeAREA_MD	0.001	0.63	0.06	1.21	0.11
TreeAREA_RA	0.001	2.11	0.28	5.04	0.41
TreeAREA_SD	0.001	0.60	0.07	1.33	0.10
TreeAREA_CV	0.001	55.11	4.83	81.53	4.56
TreeNLSI	0.001	0.06	0.00	0.06	0.00
TreeLSI	0.001	3.98	0.37	6.54	0.38